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# DURABLE LUSTER AND IMPROVED STRENGTH FOR COTTON YARN AND FABRIC

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# PREFACE

Scientists at USDA's Southern Utilization Research and Development Division have recently made important advances for improving the luster and strength of cotton yarns and fabrics. The purpose of this report is to stimulate the cotton industry's interest and research toward the utilization of these improvements for the benefit of agriculture, industry and the consumer. In addition, the report is designed to apprise industry of its opportunity to participate with USDA's Southern Utilization Research and Development Division in commercial feasibility studies and to assist in evaluating future research results on these properties of cotton.

# DURABLE LUSTER AND IMPROVED STRENGTH FOR COTTON YARN AND FABRIC

and others 3a

by

A. L. Murphy, M. F. Margavio, C. M. Welch, T. L. Ward, and
L. W. Mazzeno, Jr.[1]

# INTRODUCTION

Present estimates indicate that about 60 percent of the approximately 12 billion linear yards of broad woven textiles of all fibers made annually in the U. S. are chemically finished cottons. Most of this finished cotton is used in the production of apparel, where appearance and aesthetic qualities and style are important in satisfying consumers. Careful investigations have disclosed that improved processing and finishing continue to offer a major opportunity for expanding the present market for cotton. This report provides additional information on the production of improved cotton apparel fabrics--a textile market that has potential for considerable growth. The research described may also find promising applications in the production of household and industrial fabrics.

Long term studies of consumers' preferences reveal that durable luster and improved strength of yarn and fabric provide the greatest additional market opportunities for cotton textile manufacturers.

The Southern Utilization Research and Development Division (SU) of the Agricultural Research Service has conducted basic and applied research on processes for improving the luster and strength of cotton textiles. Research on these and other important cotton characteristics are continuing at SU as well as in other laboratories.

Communication and cooperation on cotton utilization research can be obtained from USDA extension specialists and scientists who are available to confer with industry personnel.

## GENERAL STATEMENT

Mercerization has long been recognized as the most practical means of improving the luster of cotton. Extensive studies have shown that luster imparted by mercerization is approximately equal to the best obtained by other techniques.

In November 1961 the Cotton and Cottonseed Research and Marketing Advisory Committee and also the SU Cotton Program Advisors emphasized that additional research was needed to develop better and more durable luster in cotton textiles designed for wearing apparel. The recommendation of these groups for research on the causes of luster and on methods of increasing it in cotton resulted in an examination of mercerization techniques used in producing luster in cotton textiles.

In a number of applications, high luster would be of greatest value when combined with high strength. This desirability is illustrated by the success of nylon and other synthetic fibers that have captured markets once held exclusively by silk. Of even greater importance would be cotton fabric that had the combination of high luster, high strength, and wash-wear properties.

Approximately 2 billion linear yards of broad woven cotton fabrics are now finished with wash-wear and wrinkle-resistance formulations that often cause a 40 to 60 percent loss in tensile and tear strength in ordinary fabrics. Obviously, the ideal finishing treatment for such fabrics is one in which, at minimum cost, high luster and high strength were imparted along with the wash-wear properties and wrinkle-resistance normally attained in crosslinking treatments.

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[1] The authors express appreciation to Mrs. M. B. Soniat for her direct collaboration in the overall planning, composition and writing of this report.

## ACCOMPLISHMENT

Highly lustrous cotton yarns can be produced by proper selection of the cotton, use of optimum yarn structure, and mercerization under carefully controlled conditions. Fabrics woven from these yarns have unusually high luster with greater tensile and tearing strength than that of unmercerized cotton fabric or fabric mercerized as piece goods of the same weight and weave (*1*).[2] The luster and extraordinarily high tearing strength obtained in this process are not diminished by subsequent wash-wear treatments, which impart high wrinkle-resistance and excellent easy-care properties to these improved fabrics. Both the luster and wash-wear properties are retained through more than 20 home laundering cycles. The average of tensile and tearing strength of the lustrous wash-wear fabrics, closely approaches or exceeds the overall strength of untreated control fabrics made of unmercerized yarn.

## PROCEDURE

Yarns were tension mercerized both continuously and in skein form. The use of an extra-long staple cotton such as Pima proved advantageous. Maximum luster is obtained in yarns that have been reverse plied to remove essentially all of the singles twist to make the cotton fiber lie as nearly as possible parallel to the fiber axis. Singeing was carried out before mercerization, and in most cases the yarns were kierboiled before singeing and mercerization, to further increase luster. Typical procedures for these operations follow:

Yarn treatment

| | |
|---|---|
| Kierboiling | 1 percent NaOH, 5 hours, 15 pounds steam, 250°F., washed, soured, and again washed, and dried slack at 190° F. |
| Singeing | Flamed at 200 yards per minute |
| Mercerization (Skein) | With 3 percent extension, 22 percent NaOH, 75 to 80°F., washed, soured, and again washed, and dried slack at 190° F. |

A number of fabrics have been woven from premercerized yarns. Examples are listed below.

Fabrics

- 90 x 42 broadcloth woven of
  - (A) Kiered, singed, mercerized 40/2 yarn.
- 116 x 66 sateen woven of
  - (B) Kiered, singed, mercerized 60/2 yarn.
  - (C) Kiered, singed, and mercerized 60/2 yarn in warp, kiered, and singed 60/2 yarn in fill
- 64 x 104 sateen woven of
  - (D) Grey 34/1 yarn in warp, singed, and mercerized 70/2 yarn in fill.
  - (E) Fabric D scoured

Resin treatment

Standard crease resistance agents were applied to the lustrous fabrics to impart wash-wear properties and to permanently fix the luster. The following formulation uses dimethylolethyleneurea (DMEU) as the crosslinking agent:

7 percent DMEU
1.5 percent catalyst H-7 (Rohm & Haas)
1.5 polyethylene
0.5 Triton X-100 (Rohm & Haas)

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[2] Italicized numbers in parentheses refer to Literature Cited at the end of this report.

The fabrics were padded in 2 dips and 2 nips to a wet pickup of 70 to 80 percent dried at 190°F. for 4 minutes and cured at 300° F. for 4 minutes. They were given an afterwash in hot water with a neutral detergent, rinsed and dried.

Mercerization equipment

Skein mercerization: On a laboratory scale, skeins of yarn were rotated as the belt of a pulley through mercerizing alkali while extended 3 percent in length. One spool of the pulley was attached to a beam counterbalanced with weights to provide necessary tension. The apparatus is described in reference (2). In determining the amount of stretch being applied, use was made of a known method of determining the "true" length of straightened but unstretched yarn skeins (3).

On a larger scale, commercial skein mercerizing machines might be adapted to stretch the yarn.

Continuous yarn mercerization: Continuous single-end mercerization of yarn at 2 percent extension were carried out on the mercerizing machine of Luther (4), and the resulting yarn was used in weaving sateen (D) described under "Fabrics." The yarn was stretched by tapered rollers in the machine.

It is possible that warp mercerization with yarns free rather than stranded (5) would be the most satisfactory way of continuously mercerizing large numbers of ends under tension, from the standpoint of economy, complete uniformity, and retention of high strength after wash-wear finishing. However, this modification has not yet been tested.

## SCOPE OF INVESTIGATION

The studies have included the effect of tension-mercerization on the properties of (a) grey, scoured and kiered yarns, (b) fabric woven from these yarns, (c) fabric after wash-wear finishing, (d) fabric after callendering, and (e) fabric after calendering and wash-wear finishing.

A systematic study of the effect of process variables such as mercerization rate, amount of tension, alkali concentration, and temperature on the above properties is in progress. The overall program also includes fundamental investigations of the morphology of the cotton fiber and various means of improving its strength properties. By permitting fabric shrinkage during mercerization and restretching either before or after washing, significant improvements can be made in breaking strength and tearing strength (7). The crosslinking of fabric woven of slack mercerized and restretched yarn results in essentially complete strength retention (8). Tension applied during wash-wear treatment considerably diminishes the strength losses normally encountered (9). It is possible that even more suitable and economical conditions may be found than those outlined above.

## EVALUATION AND RESULTS

### Luster

The ratio of specular (or mirrored) reflectance/diffuse (or scattered) reflectance is a textile property measurable by commercially available electronic equipment such as the Hunter Reflectometer or the Photovolt Reflectance and Gloss Meter. This ratio can often be correlated with the averaged luster ratings made visually by a group of nontechnical observers. The luster of fabrics determined visually or by instrumental measurement bears a relation to the amount of luster in the yarns, but the particular fabric weave used also has a very great effect, either enhancing or concealing luster (6).

Dyeing the fabric usually increases both the measured contrast and also the visible luster. The effect varies somewhat with the particular dye used.

Indices of luster were determined by a method developed by Ward, et al., which correlated visible luster with measured reflectances (10) (11).

For undyed 90 x 42 broadcloth woven of kiered and singed 40/2 yarn, the contrast ratio was 0.91 whereas for the same type of fabric woven from kiered, singed, and mercerized yarn (fabric A listed previously), the ratio was 1.06.

For undyed 116 x 66 sateen woven of kiered and singed yarn, the contrast ratio was 1.05. This value was raised to 1.26 by the use of kiered, singed, and mercerized yarn (fabric B). The ratio was 1.37 for fabric C, 1.23 for fabric D, and 1.53 for fabric E. After the fabrics were dyed with Indanthrene Blue (6 percent on weight of fabric), the values for B, C, D, and E were raised to 2.05, 2.49, 2.43, and 2.83, respectively. These dyed fabrics were impregnated with DMEU, dried, calendered, and cured, after which they gave values of 4.72, 4.89, 5.53, and 6.80.

When the undyed samples of A, B, C, D, and E were treated with DMEU, the contrast ratios differed by only 1 to 12 percent from those before resin treatment, and little or no decrease in luster could be detected. After resin treatment the luster was durable for more than 20 standard launderings.

## Wash-Wear Properties

DMEU treatment imparted the same wash-wear properties to the lustrous fabrics as it did to fabrics woven of ordinary yarn. Broadcloth A, for example, showed a wash-wear rating of 5 both before and after 20 launderings. Its dry crease recovery (Warp & Fill) was 275°F. as compared with 267°F. for broadcloth woven from kiered and singed yarn.

## Strength Properties Before and After Resin Treatment

When 90 x 42 broadcloth was woven of kiered and singed yarn, the breaking strength (warp) obtained on this control fabric was 105 pounds. The same type of broadcloth woven from kiered, singed, and mercerized yarn (fabric A) showed a breaking strength of 107 pounds. After DMEU treatment, the strength of the control broadcloth woven of unmercerized yarn decreased to 58 pounds, whereas the strength of fabric A after resin treatment was 86 pounds. Thus fabric A possessed 82 percent as much strength after resin treatment as the unmercerized control possessed before resin treatment.

The tongue tearing strength of the control fabric before crosslinking was 3.8 pounds in the warp, whereas that of fabric A was 4.8 pounds. After DMEU treatment, the value for the control fabric was 3.3 pounds and for fabric A, 7.0 pounds. In this test, the tearing strength of fabric A after resin treatment was nearly twice as great as that of the unmercerized control without resin treatment.

In Elmendorf tearing strength tests, yarn slippage and withdrawal occurred in both the test and control fabrics. Nevertheless, the values obtained were reproducible and indicated that the fabric woven of mercerized yarn was about 66 percent stronger than the fabric of unmercerized yarn.

Resin treatment of fabric A caused only a 15 percent loss in Elmendorf tearing strength whereas there was a 40 percent loss in the mercerized control. Compared with the unmercerized control, fabric A after resin treatment was 40 percent stronger in tearing strength than the control fabric not resin treated, and more than twice as strong as the resin-finished control.

## Fabric Hand, Softness, and Cover Factor

In contrast to conventional fabric mercerization under tension, which may cause stiffness in many fabrics, the fabrics woven from mercerized yarn were very soft and supple. This effect was borne out by Tinius-Olsen stiffness measurements on both broadcloth (fabric A) and sateen (fabric B). Broadcloth woven of kiered, unmercerized yarn had approximately the same bending moment ($7.0 \times 10^{-4}$ pounds in the warp and $7.5 \times 10^{-4}$ in the fill) as fabric made of kiered and mercerized yarn ($7.6 \times 10^{-4}$ in warp and

$8.5 \times 10^{-4}$ in fill). However, after laboratory mercerization of the control fabric at 1 1/2 percent extension in both directions, its bending moment increased to $22.7 \times 10^{-4}$ in the warp and $25.5 \times 10^{-4}$ in the fill. Thus the bending moment of fabric woven of mercerized yarn was less than one-third that for fabric given tension mercerization in fabric form. A similar effect was noted with sateen. After resin treatment, the bending moment of the broadcloth (A) was as low or lower than before treatment.

The air permeability of broadcloth A was twice that of the broadcloth woven of kiered, unmercerized yarn, but was less than one-third that of the control fabric mercerized at 1 1/2 percent extension. For sateen B, the air permeability was double that of sateen woven of kiered, unmercerized yarn, but was 80 percent that for control fabric mercerized at 1 1/2 percent extension.

## ECONOMICS

Information on economics will be made available to industry as soon as the evaluation of significant data has been completed.

## SUGGESTED USES

These fabrics will be useful when appearance factors of luster and wrinkle resistance need to be combined with performance factors of easy-care and high strength. Uses in apparel include men's suitings, hosiery, shirts, suit linings, ties; women's aprons, uniforms, blouses, coats, jackets, suits, dresses, negligees, slacks; children's coats, jackets, dresses, hosiery, playsuits, linings. Industrial uses include luggage lining, casket linings, flags, umbrellas, and woven labels.

## SAMPLES

Samples of yarn and fabric are available from Dr. B. H. Wojcik, Assistant Director for Industrial Development, SU, New Orleans, Louisiana.

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